This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

72
26A
India

RESOLUTION

BY THE

HON'BLE THE LIEUTENANT GOVERNOR

OF THE

NORTH WESTERN PROVINCES,

IN THE PUBLIC WORKS (IRRIGATION BRANCH) DEPARTMENT,
No. 5741., DATED 22ND OCTOBER, 1866.

ON THE

REPORT OF THE GANGES CANAL COMMITTEE;

AND

MEMORANDUM

DATED 18TH AUGUST, 1866,

BY THE

CHIEF ENGINEER, IRRIGATION WORKS, PUNJAB,

ON ALTERATIONS IN THE PROJECT FOR REMODELING THE GANGES CANAL,
PROPOSED IN PARAS. 107 TO 111 OF THE COMMITTEE'S REPORT.

ROORKEE:
PRINTED AT THE THOMASON CIVIL ENGINEERING COLLEGE PRESS.
MDCCCLXVII.

JAMES JOHNSTON, SUPERINTENDENT.

U Prov. Ic. 4

RESOLUTION

BY THE

HON'BLE THE LIEUTENANT GOVERNOR

OF THE

NORTH WESTERN PROVINCES,

IN THE PUBLIC WORKS (IRRIGATION BRANCH) DEPARTMENT,
No. 5741., DATED 22ND OCTOBER, 1866.

ON THE

REPORT OF THE GANGES CANAL COMMITTEE;

AND

MEMORANDUM

DATED 18TH AUGUST, 1866,

BY THE

CHIEF ENGINEER, IRRIGATION WORKS, PUNJAB,

ON ALTERATIONS IN THE PROJECT FOR REMODELING THE GANGES CANAL,
PROPOSED IN PARAS. 107 TO 111 OF THE COMMITTEE'S REPORT.

ROORKEE:
PRINTED AT THE THOMASON CIVIL ENGINEERING COLLEGE PRESS.
MDCCCLXVII.

No. 5741. of 1866.

Resolution

BY THE

Hon'ble the Lieutenant-Governor

OF THE

NORTH-WESTERN PROVINCES,

IN THE PUBLIC WORKS (IRRIGATION BRANCH) DEPARTMENT.

DATED, NYNEE TAL, THE 22ND OCTOBER, 1866.

GANGES CANAL REMODELING.

Note by the Chief Engineer, Irrigation Works, North-Western Provinces, No. 177c., *Dated Nynee Tal, the* 16*th October*, 1866.

REFERENCES.

A.—Memorandum of the measures recommended to be taken for remodeling the Ganges canal by the Committee (Colonel Strachey, *President*) of January, 1864.

B.—Report on the Ganges canal, by Captain J. Crofton, R.E., dated 23rd November, 1864.

C.—Resolution, No. 227c-1110, dated 27th February, 1865, by the Government of India, Public Works Department, sanctioning Major Crofton's Estimate.

D.—Letter No. 55c., dated 18th January, 1866, from Secretary to the Government of India, Public Works Department, communicating intention to appoint a Committee.

E.—Letter, No. 83c., dated 25th January, 1866, from Secretary to the Government of India, Public Works Department, communicating instructions regarding the preparing and affording information to the Committee.

F.—Resolution No. 204c., dated 24th February, 1866, by the Government of India, Public Works Department, nominating the Committee (Colonel Lawford, *President*) to report on the propriety of proceeding with Major Crofton's project, with reference to Sir A. Cotton's objections to it.

G.—Letter, dated 21st May, 1866, from Sir A. Cotton, to Secretary to Government, North-Western Provinces, Public Works Department, forwarding copy of his letter to Secretary of State for India, objecting to the Committee appointed by Government of India.

H.—Report of the Ganges Canal Committee (Colonel Lawford's), dated 18th June, 1866.

I.—Memorandum, dated 18th August, 1866, by Major Crofton, on the Modifications proposed in paragraphs 107 to 111 of the Committee's Report.

REMARKS AND RECOMMENDATIONS.

THE Committee on the Ganges Canal have condensed their Report into five conclusions, viz. :—

"I.—That the construction of a weir across the Ganges below the confluence of the Solani, with other necessary works for supplying water to the canal, at an estimated cost of Rs. 1,12,86,314, cannot be recommended.

"II.—That the project for opening an additional canal-head, including the construction of a weir on the Ganges at Rajghat, or other point in that part of the river, at a cost of Rs. 1,13,04,170, for bringing under irrigation lands not now watered by the canal, is feasible, but should be held in abeyance until the probable returns appear more proportionate to the outlay than at present.

"III.—That the construction of a weir across the Jumna at Toghlukabad, with a canal for the irrigation of that part of the Doab below Allygurh not under the influence of the Ganges canal, at a probable cost of Rs. 35,45,701, inclusive of branch channels, is practicable, and that the project should be further investigated; but they are of opinion that it cannot be substituted for any portion of Major Crofton's project.

"IV.—That Major Crofton's project for remodeling the Ganges canal should be proceeded with, subject to the modification suggested in this Report.

"V.—That the construction of a permanent weir across the Ganges at Hurdwar, though not indispensable while the present reduced quantity of water is passed down the canal, will become a matter of absolute necessity in order to maintain, without risk of interruption, the full supply of 7,000 cubic feet per second."

2. One member alone of the Committee, Mr. George Sibley, dissents from the above, "mainly as to conclusions Nos. III. and IV.,—the first negativing the proposed canal from the Jumna near Delhi (bringing 3,300 feet per second to complement the present 4,400 now brought down by the main canal) as a substitute for the remodeling above the junction; the second recommending that the remodeling according to Major Crofton's plans (with certain modification) be at once proceeded with."

3. Mr. Sibley would substitute for the remodeling of the Ganges canal channel above the 158th mile, the construction of the new canal from the Jumna near Delhi, which was originally proposed by Major Crofton.

4. As regards the main point at issue, I agree with the majority of the Committee, and for the following reasons :—

I.—It is not probable that a larger supply than 1,500 cubic feet per second can be obtained from the Jumna and Hindun rivers together throughout the year. But, whatever that supply may be, the Ganges Canal can profitably, and should undoubtedly, be put in a state to secure with ease, to carry safely, and to distribute to the best advantage every drop, of the ordinary constant supply available from the Ganges river at Hurdwar. By the "ordinary constant available supply" is to be understood that supply which, in an ordinary average season, can be obtained from the river uninterruptedly; or, in other words, the minimum discharge of the river in an

average year. For, in Northern India, as a general rule, it would not appear to be advisable to increase the capacity of an expensive permanent canal beyond the ordinary minimum discharge of the river from which it is derived; and, on the other hand, to remain satisfied with a smaller capacity than this, would be to slight the proffered gifts of Providence,—to reject the benefits of which the country so greatly stands in need. The latter position is not likely to be disputed, and the former may be accepted on the consideration, that the amount of "irrigating duty" done by a cubic foot of water during the *Khureef* or autumn crop, is less than the duty in the *Rubbee* or spring crop in the proportion of from one to two to that of one to three-and a-half. On the assumption, then, that the value to Government of a cubic foot of water for the autumn crop is to its value during the spring crop as one to two, the result of increasing the capacity of a canal, so as to enable it to carry half as much more during the autumn crop than it can obtain during the spring crop, would be an addition of only one-sixth to the gross returns from water-rate. If we assume the autumn value of a cubic foot to bear to the spring value the proportion of one to two-and-a-half, then the result, as above, would be an addition of one-seventh to the returns. And, lastly, if we assume one to three as the proportion, the result would be an addition of only one-eighth.

II.—Besides the comparative smallness of this increase, in proportion to the amount of extra work required to produce it, there would be great practical inconvenience in having to irrigate from different levels of supply at different seasons of the year; and, as regards navigation, the head-way, which would be ample during the spring crop, would be very considerably diminished during the autumn crop;—extra height would therefore have to be given to all bridges, &c.

It may be laid down therefore as a general rule in Northern India that the minimum supply in a river should fix the capacity of the canal derived from it.

Under certain conditions, however it may be expedient to relax the rule; but each case must be gone into on its own merits.

It does not appear to me that, in the case of the Ganges canal, the rule can be conveniently or advantageously relaxed. The detailed estimates will show whether this can be done in the case of the new Jumna canal. I propose to start the survey for the canal at once, under the executive charge of Mr. James Parker, who is daily expected on his return from leave in England, or of his *locum tenens*, Mr. Clinton Anderson.

5. Mr. Sibley, in paragraphs 18 to 21 of his Appendix (A.), discusses the question of the minimum discharge of the Jumna and Hindun rivers combined, On this point the information with which I supplied the Committee was as follows:—

JUMNA RIVER.

At Delhi.

19th December, 1864, ...	...	935 cubic feet per second	(Lt. Moncrieff).
18th January, 1865, ...	...	1,613 „	(Sergt. Caernarton).
19th December, 1865, ...	...	828 „	(Mr. Garbett).
19th January, 1866, ...	...	5,004 „	(Mr. Garbett).

At Agra.

19th January, 1865, ..	...	1,153 cubic feet per second	(Captain Stewart).

HINDUN RIVER.

Near Delhi.

19th January, 1865,	...	...	357 cubic feet per second (Sergt. Caernarton).
12th January, 1866,	...	...	501 „ (Mr. Garbett).

The discharges of January 1866, must be rejected, as heavy rain had fallen in the hills, and generally, before the observations were made. The remaining discharges show conclusively that 1,500 cubic feet per second is the extreme estimate of the supply available from these rivers throughout the cold weather. Further observations may even reduce the above estimate.

6. Mr. Sibley's argument is based on his belief that the river Jumna at Delhi is lowest during the month of April. Mr. Sibley is well acquainted with the peculiarities of the Jumna at Allahabad, but he has not had the same opportunities for studying it higher up, or he would have known that December and January are the months in which the river is lowest there, as a general rule; December when the cold-weather rains are early, and January when they are late. The same rule holds good on the Ganges, as also on all the rivers of the Punjab.

7. A daily register of the height of water in both the Jumna and Hindun is now kept at Delhi.

8. As to the minimum discharge of the Ganges river at Hurdwar, I supplied the Committee with the following data:—

Discharges taken by Captain Forbes on the 27th January, 1865.

Above the canal bunds,	...	...	...	5,710 cubic feet per second.
Below the canal bunds,	...	...	...	572 „ „
Ganges canal at Myapore,	...	...	...	5,114 „ „

The two latter, aggregating 5,686 cubic feet per second, are checked by the former and the agreement is sufficiently close. The river was so abnormally high in January 1866, owing to heavy rain, that the results then obtained must be rejected.

It appears from the above that, in January 1865, the whole of the visible supply of the Ganges river, with the exception of 596 cubic feet per second, was turned into the canal. I have no reason for supposing that the rivers were abnormally low in the cold weather of 1864-65.

9. I have gone thus into detail concerning minimum discharges, because it appears to me that the whole question hinges on this one point. If only 5,700 cubic feet per second can be obtained from the Ganges at Hurdwar throughout the year, it seems inexpedient to go to the expense of adapting the canal for carrying 7,000. And again, if only 1,500 cubic feet per second can be had from the Jumna and Hindun combined, it would scarcely be advisable to make a canal for 3,300. But (as observed in paragraph 4) this case can be taken up and decided on its own merits with the aid of the detailed estimates.

10. I would here remark on the urgent necessity for systematically observing the discharges (the minimum discharges especially) of all rivers and streams in India, at as many points as can be conveniently arranged for, and for a continued series of years. In 1855, when the late Court of Directors, called for information regarding works which might be advantageously carried out, I brought forward this

matter (among others) as being the very first step in any general scheme of irrigation; showing how little we know of the extent of water-supply really available, and how impossible it was to initiate a successful scheme without full knowledge on this head. Every year since then I have had taken as many observations as my own limited establishment, and the kindness of officers in other departments, could furnish. As yet, however, the results are small.

11. In the 18th paragragh of his "Dissent," Mr. Sibley recommends that the inward-curving tail walls of the falls should be altered at once. This measure was recommended as part of his remodeling project by Major Crofton, and its cost provided for. Mr. Sibley thought the alteration should be carried out at once: however, as the holes below falls were found to be getting shallower, instead of deeper, it was considered better to wait for the next closure, when the work could be got at more easily with a dry canal. The alteration was carried out during the late closure in August last. It should be mentioned that the tail of the Nirgajnee (or Belra) fall, alluded to in Mr. Sibley's 17th paragraph as of better design, was the first planned by Sir P. Cautley after his Eastern Jumna Canal falls. The second arrangement was devised as "being more compact than the original design, and being greatly more economical in its construction. It was in fact the enormous excavations which were required at the falls at Belra, the difficulty of disposing of the earth and laying out the embankments, and the extensive area, demanding box-work at the tail, that led me to the modification as exhibited in Diagram 106."—*See* page 171 of Volume II. of Sir P. Cautley's Report of 1860. It should also be noted that the Nirgajnee fall is founded on stiff clayey soil, while the other falls are built in almost quicksand,—a fact which is alone sufficient to account for the smaller amount of scour which has taken place below the former work.

12. On Mr. Sibley's 19th paragraph it need only be observed that "the Sewalik sandstone lately brought in," fairly represents the kind of stone which alone can be had in any quanity, and at a moderate cost, from the Sewaliks. It is true that the wealthy Mahajuns of Hurdwar and Jowalapore have gone to great expense in selecting a small quantity of very fine sandstone adapted for carving for door-jambs, &c.; but it does not therefore follow that this fine stone is to be found in sufficiently large quantities for the canal works; or that if found, it would be as well adapted for them, or as cheap, as Agra, Bhurtpoor, or Delhi stone. The results of the quarrying experiment already made on a large scale (*see* paragraphs 130 to 132 of the Committee's Report, and my separate Report, No. 181c., of this date) have I think settled the point. The finer sandstone was not unrepresented in the experiments.

13. I agree with Mr. Sibley as to the time which would be required to carry out Major Crofton's project. I do not think the work (even as modified by the Committee) could be done in two closures of three-and-a-half months each. No doubt, as observed by the Committee, much can be done in a short time where a single work only is concerned; but the causes and chances of delay are so multiplied in the case of numerous works, all pushed on simultaneously, that I, for one, should not like to run the risk. Besides, it would scarcely be possible to collect the requisite number of workmen for such short working seasons.

14. We may now examine the modifications which the Committee propose to make in Major Crofton's project, with the remarks of that officer on them. *The*

excavation (para. 107).—The Committee propose, by raising the crests of the falls, to deepen the channel, and so to increase its carrying capacity, instead of attaining the object, partly by widening, and partly by deepening, as proposed by Major Crofton. That is to say, the depth of seven feet at Roorkee (corresponding to the supply to which the canal is now limited) would be increased to 11·3 feet by Major Crofton's proposal, while 56 feet would be added to the original width of the channel. On the other hand, the Committee would leave the width untouched, and would increase the depth to 14·5 feet, or more than twice the present depth.

Here I think Major Crofton's design is to be preferred; for independently of the greater ease of working with the smaller depth, he shows that the saving in cost of earthwork, effected by the Committee's modification, would be only half the anticipated saving, as the banks must in any case be put into proper order, and a good towing-path provided; that the head-way for navigation would be seriously interfered with in five out of eight canal bridges; that lock-walls, bridges, and gates must be raised also, as well as the superstructure of all falls, old and new, and the canal banks for some distance above these works.

To which I may add that the result of long continued observations on canals has convinced me that, in the case of bed and banks of the same soil, when the velocity of the current is so great that there is a tendency to erosion, the banks will suffer before the bed if the depth of water is greater than one-thirteenth of the bottom width, or say one-fifteenth of the mean width. According to the recommendations of the Committee, the channel would have a depth of water of more than one-twelfth its mean width; and the mean velocity of the current would be two-and-three quarters feet per second, which is fully as much as the soil can stand. Under these circumstances, it is probable that it would be both troublesome and expensive to keep up the tow-path, without which navigation cannot be effectively carried on.

15. *Grating and Lock at Kunkhul Bridge* (para. 108).—Here I agree with the Committee. Before the Committee met, I had drawn out fresh designs for the navigation arrangements from the Kunkhul bridge to the Puttree super-passage, in which a lock at the head of the present navigation channel was substituted for the one proposed at the Kunkhul bridge, the grating there being also omitted, and the navigation being continuous along the present channel, thus doing away with the two proposed new entrances and new exits to and from it. The fault of the navigation channel at present is that it silts up rapidly, and thus becomes too narrow for boats to pass conveniently. The cause is, that at present a sufficient supply of water cannot be passed along it. I have therefore designed a new form of lock, in which a hinged sloping grating, with balanced shutters, takes the place of the upper-gate, and through it a full supply can always be run, except at the moment of a boat's passage. A lock on this principle in now being built on the Eastern Jumna Canal, for the sake of experiment.

16. *New Fall and Lock at Roorkee* (para. 109).—Here I agree with Major Crofton. Independently of other reasons, a fall at Roorkee would be of so great value to the Workshops, that I should be inclined to make a push for it. As noted by Major Crofton, the percolation through the brick-work arches of the Solani aqueduct is entirely due to the want of water-tight covering over them.

It is pretty certain that this percolation will almost entirely cease as soon as the covering has been given. There was a case in point on the Baree Doab Canal, that of the Deenanugger aqueduct, which was completely staunched by covering it with stiff unctuous clay, protected by brick-on-edge laid over it dry. In all probability the expense of protecting the earthen channel from the effect of increase of velocity given to the current by the Committee, would be greater than that of enabling the aqueduct to carry thirteen feet of water.

The velocity of four feet per second for such a distance, as per the Committee's modification, would prove a serious obstacle to navigation, but the chief objection to it is, that it would considerably retard the process of natural puddling, which takes place with moderate velocities, by the induction and interposition of the finer particles of silt between the coarser particles of the soil composing the bed and banks of a channel. On a long line of earthen embankments, like that across the valley of the Solani, the process of natural puddling cannot be too much assisted.

17. *Additional Arch to increase the Water-way under Bridges* (para. 111). —Whether the additional arch is absolutely necessary or not, depends on the practical requirements of navigation. I think the bridges may in the first place be allowed to stand as they are, but with the addition of protective stone-work to enable the earthen channel to stand the increased velocity through the bridge of three and two-thirds feet per second. Afterwards, if this velocity is found to seriously interfere with the haulage of boats, the additional arch can be given by taking advantage of the ordinary annual closures.

18. *Time in which proposel Work can be executed* (paras. 112 to 114).— I do not agree with the Committee that the works can be executed during two short closures of about three-and-a-half months each. The Committee's estimate of the loss to be incurred by a closure during March, April, and May, is probably as accurate an estimate as can be made, considering the nature of the questions involved. But it seems needless to pursue the matter further. It has already been explained that examples of single works executed in a very short time afford no criterion for the case in point, where the works are so numerous, and the number of men required so great, and the risks so multiplied.

But the evils of a long closure are so great, that every effort must be made to avoid it. I propose, therefore, first to experiment on what can be done with a running canal. There appears to be no reason why new falls should not be built in the still water formed by turning the canal round the intended sites, and shutting off the requisite portions of the present channel. I do not anticipate great difficulty from the cisterns below falls.

With under-sunk deep foundations for piers, &c., in sand, the cisterns would require no other flooring than loose stone. In clay, pumps can be used. Major Crofton is now experimenting on the falls of the Baree Doab canal at my request, in order to ascertain the depth to which materials of different kinds, as shingle, gravel, clay, and sand are acted upon by a water falling through a grating. The object of the cistern however is not only to give a cushion of water over the floorings, but also to afford space in which the eddies and swirls of the descending currents may be changed into steady onward flow; and for this reason, I prefer that the cistern should end with a long counter-slope if possible.

The alterations to the old falls are likely to prove more troublesome, especially above Roorkee. I have designed an addition to these falls, which can be applied during an ordinary closure; if successful, the chief difficulty will no longer exist; if unsuccessful, and if no better expedient can be devised, the prolonged closure of the canal will remain as a last resource.

For the earthwork, a long closure is not required.

19. *The large proportion of "artificial" to "natural flow" irrigation on the Cawnpore and Etawah branches* (para. 116.)—This I believe to be due principally to the water-surface in those branches being at too low a level to command the country on either side without the intervention of long lines of rajbuhas, a considerable length of the upper portion of which must be non-irrigating. The smallness of the present supply of water lowers the surface still more. The levels of the country are not everywhere favorable for the distributing channels; the water-sheds are tortuous and interrupted; in places the Etawah branch has had to be carried on sidelong ground, to the great disadvantage of the irrigation on the higher side. But it must be remembered that the system of distributing channels is far from complete, on the Etawah branch especially. In accordance with the orders of Government to suspend the extension of rajbuhas, as recomemended in the last paragraph of the report of Colonel Strachey's Committee of January 1864, funds have been withheld. The Budget grant for expenditure on rajbuhas in the present year is but a fourth part of the sum asked for. Under these circumstances effective distribution of water cannot be expected. A project is now being drawn up for the remodeling of the Etawah branch, for the improvement of both irrigation and navigation. But I object to the introduction of weirs or of any system of irrigation whereby the velocity of the water in the channel may be reduced below the normal standard of two-and-a-half feet per second. This system was tried for many years on the Rohtuck branch of the Western Jumna canal with very objectionable results. But perhaps the Committee wished merely that the surface level of the water should be raised, without checking the velocity of the current. It should not be forgotten that Sir P. Cautley's project included lockage into the Jumna on this branch.

20. *Cross canals for Navigation* (para. 119).—These I believe to be essential to the full development of navigation. Sir P. Cautley has proposed two cross lines to the Jumna.—*See* page 419, Vol. I. of his Report. In my project of 1850 for the Baree Doab canal, I proposed such a system for the Punjab, in connection with navigable irrigation canals. But each line must be taken up on its own merits. At present the main canal affords more than ample employment for the executive establishment.

21. *The width of Locks* (para. 120).—I agree with the Committee that, under present circumstances, it is advisable to retain the present width of sixteen feet. Plans were drawn out last cold weather for attaching locks, twenty feet wide, to all falls; and it was found that the additional cost (over and above Major Crofton's estimate, which allowed for sixteen feet only) was very great. I should be inclined to utilize the existing locks and lock-channels, by fitting the locks, with the hinged grating already described, so as to enable the full supply to pass. Deposit of silt will thus be prevented, and the proper width of channel at water-line will be maintained.

In connection with each new fall I would build two locks, one on either side, the locks forming a portion of the fall, and discharging as much water in proportion to their width as any other part of the fall. With locks attached to falls, repairs cannot be easily executed unless the canal is closed. It is advisable therefore to provide two locks, one of which at least shall always be in perfect order. If navigation increases, as doubtless it will to a large extent, two locks will be everywhere required. and it is much easier to build them at once, than it will be to add them hereafter. The additional expense of building them is not very great.

While on the subject of navigation, I may mention one alteration in the disposition of the tow-paths, &c., as projected by Major Crofton, viz., to place the five-feet towing-path on the left, and the fifteen-feet path on the right bank. This would seem advisable for the following reasons:—There is at present no roadway on the right bank—no means whatever of riding along it and inspecting it—consequently the right bank has everywhere fallen into a very neglected state. The rain cuts it into ravines, and the soil is washed down into the canal in large quantities. Much of the excessive silting up of rajbuhas is due to this cause. The plantations also on the right bank not being easily visited, are neglected. It is as well, too, that access to rajbuha heads on the right bank should be facilitated. Again, the course of the canal, for the length proposed to be widened, being generally north and south, the prevailing strong westerly winds make the right or sheltered bank preferable for towing, even though it be necessary occasionally to cross over from one side to the other. It certainly would facilitate towing very much, were choice of side possible; and it is to be hoped that eventually there will be uninterrupted passage for boats by water, and for cattle by land, along both banks. Again, in cutting the fifteen-feet tow-path on the right bank, it will not be necessary to interfere with the present road-bank on the left, or with the thriving plantations close outside it. These would be considerably encroached upon were the wider tow-path excavated from the left bank. In the actual execution of the work, by placing these paths three feet above the level of the water instead of two feet, and by making the side-slopes for that three feet one in one-and-a-half, instead of one in two, an extra width of one-and-a-half foot is added to the paths, with a small saving in cubical contents of excavation. This has already been carried out above Roorkee.

22. *New Branch Canal from Roorkee to Deobund* (para. 121).—This project must be kept in abeyance till the actual supply available from the Ganges river shall have been ascertained. As far as my information goes at present, there is no water to spare for it (the Futtehgurh branch must first be provided for), and just now there is much work to be done of a more pressing nature.

23. *Periodical closure of Canal* (para. 122).—The exact time of closure must depend very much on the nature of the season, and must be left to the discretion of the Superintending Engineer. But, as a general rule, August is the month, a closure during which is least hurtful to irrigation. If heavy rain falls in January the canal may sometimes be closed in that month. The Ganges canal was closed for inspection and repair last August, after having been run uninterruptedly for 23 months, and it is probable that it will now be closed annually at the same season; but this must depend on the urgency of the work to be done and on the weather. It must be noted, however, that there are serious objections to a closure in August.

The unhealthiness of the season not only endangers the lives of the Engineers and of their men, working in the half-dried bed of the canal, but adds to it the difficulty of obtaining labor; and the heavy falls of rain, while making the cultivators independent of artificial irrigation, and so rendering it possible to close the canal, are not favorable to the operations of the mason and bricklayer, or indeed to work generally.

24. The Superintending Engineer's report on the state of the canal channel, and of the works generally, on the occasion of the last closure, will be annexed as an Appendix (A.) to this Memorandum, if it arrives in time. I give here an abstract of his demi-official report.

"From Myapore, the head of the canal, to Roorkee, 19th mile, the masonry works were found to be uninjured. Between Roorkee and Jaolee, 49th mile, the bridges were uninjured, and the sole damage done to falls consisted in the stripping off of some of the brick-on-edge covering to ogees and flooring of three falls. The Jaolee fall had a settlement (independent of the foundations) of a portion of the flooring of two bays, which however occurred in September, 1864, and which had remained *in statu quo* ever since. Below Jaolee, four falls had a little of the brick-on-edge stripped off ogees. All other masonry works were uninjured.

"The earthen channel was found to be in good condition, as compared with its state in 1864. All the holes in the bed, which necessarily exist below falls, and below bridges through which there is a considerable rush of water, have not only become shallower, but have moved further off from the works than they were formerly."

25. *Proposed Weir across the Ganges at Hurdwar* (paras. 123 to 128). The Committee "would not advocate the construction of a permanent weir across the Ganges, if 5,000 cubic feet per second were to be the full supply of the canal;" and they add, that comprehensive knowledge of the locality is requisite before a detailed plan can be furnished. The Engineer employed in obtaining the necessary details had to be removed to take part in the survey of the Ganges Khadir before the arrival of the Committee, in obedience to Government of India's No. 83c., dated 25th January, 1866. (Reference E.) no one else being available for the duty.

With reference to the Committee's 126th paragraph, concerning the exaggerated reports of the so-called failure of the Ganges Canal during the famine year, I may quote Mr. T. Login's opinion:—"During the hot season in 1860, there was an unprecedented demand for canal water, owing to the want of rain; and in the attempt to push down a larger supply than was necessary in former years, a branch of the Ganges opposite Hurdwar had its bed scoured out at every flood. The water required for the canal escaped down the channel. Thus when there was the greatest demand there was only half a supply. Fearing the recurrence of this state of things, an urgent demand was made for £30,000, to be expended within the current year for head-works. Hence arose a report that the canal had failed for want of head-works. In the early part of 1861 an expenditure of £1,000 was sanctioned for protecting the bed of the Hurdwar channel, and the works for the purpose, consisting of temporary bunds, proved effective. The temporary bunds used cost altogether about £2,000 per annum, and they send down as much water as is required; still there is no doubt that permanent heads would be an improvement;

only it is very questionable whether they would pay at present, so they may be deferred."

Colonel Morton's opinion on the necessity for permanent head-works is annexed as Appendix B.

With the present limited requirements of the Ganges canal, the Executive Engineer of the Northern Division (Captain Forbes) can maintain the supply with almost absolute certainty. But a less experienced, or a less energeticofficer, might not prove equally successful.

26. With reference to the 54th paragraph of Government of India's Proceedings, No. 227c-1110, dated 27th February, 1865 (Reference C.), on Major Crofton's suggestion that a point opposite Kunkhul, a little below the present head of the canal, might be found suitable for new head-works, as being below the point where all the branches of the Ganges re-unite, the levels already taken show that the scheme is not feasible. Nor does there appear to be any point where a dam or weir across the Ganges could be built, so as to serve both for the Ganges canal, and for a new canal from the left bank of the river, to irrigate North-Western Rohilkund during the rainy season.

27. On *stone from the Sewalik hills, and from the Himalayas, for the Canal works*, I have already remarked (in paragraph 12). In the Committee's report, as printed, there is an erratum on page 39. The crushing weight for "middling" stone, dry, should be 4,356 lbs. per square inch, not 5,356 lbs. And it may be noted, for the sake of clearness, that on pages 40 and 41, the three paragraphs beginning,—"I have now the honor to inform you," and ending "the search for it shall not be abandoned," are extracts, not from my letter of the 31st May, between two paragraphs of which they are inserted, but from a subsequent letter of the 13th June last.

28. On the question of the *Allahabad Extension*, I agree with the Committee. As already stated in the case of cross canals of navigation, each such project must be taken up on its own merits.

29. *Financial state of the Canal.*—In paragraph 144, for "the annual receipts will be increased by eight annas per acre on about 583,000 acres, or nearly three lakhs of rupees," might be more correctly read, "the annual receipts will be increased by eight annas per acre on about 1,749,000 acres, or $8\frac{3}{4}$ lakhs of rupees." And in paragraph 148, for, "but if the enhancement of land revenue due to the canal, which is estimated approximately at upwards of Rs. 2,90,000, be credited in the receipts, the return for the year would be five per cent. on the outlay," might be more correctly read, "but if the enhancement of land revenue due to the canal which is estimated approximately at Rs. 8,74,500, be credited in the receipts, the return for the year would be very nearly $7\frac{3}{4}$ per cent. on the outlay."

The above errors were caused by the Committee's not distinguishing between the area of land actually watered during the year, and the area which in an average well-irrigated district is assessable as "irrigated land." The Committee quote paragraphs 8 and 9 of Section XVIII. of my project of 1850 for the Baree Doab canal; but the statements there given require to be read with the context. Reference is made to paragraph 6 of the same Section, which shows that in the Meerut district (the best irrigated on the Eastern Jumna canal, and to which paragraphs 8 and 9

refer) *actual watering* is practised to the extent of one-third only of the total area of land which comes under the denomination of "highly irrigated." Hence the land revenue enhancement of eight annas an acre on the area assessed as "irrigated land" must be calculated on three times the area actually watered. This will be readily understood when it is considered that land which is left fallow, as well as land on which rain-crops are grown in any year, is not chargeable with water-rate for that year, but is chargeable with the assessed enhancement of land revenue. It is so of course every year during the term of the settlement, no matter what its state may be, whether it be irrigated or unirrigated, cultivated or uncultivated.

The above estimate of eight annas per acre on three times the area actually watered is of course equivalent to one-and-a-half rupee per acre on the area actually watered, and as stated in my report quoted by the Committee, it is based on the statistics given by the late Colonel R. Baird Smith in his valuable article on "Canals of Irrigation in the North-Western Provinces," published in the *Calcutta Review* for September, 1849; and I have since been informed by The Hon'ble the Lieutenant-Governor that Mr. Muir assumes the same rate of one-and-a-half rupee per acre as a general average. It may therefore be adopted with confidence.

In further explanation, I may observe that I took the Meerut district rate as a fair average for the whole canal, because it is centrically situated, being neither naturally moist, with water near the surface, as is Seharunpore; nor as dry as Bulundshuhur or Etawah. Mr. H. LePoer Wynne, the Settlement Officer of the Seharunpore district, has contributed a valuble paper, copy of which I annex (as Appendix C.), explaining his method of estimating the amount of enhancement of land revenue due to canals, and illustrating it by a statement of enhancement for the Seharunpore district. It appears from his statement that the average rate on the area of land actually watered at the time of his settlement is 1 and 1-16th rupee per acre. This rate for the naturally moist and well-irrigated district of Seharunpore, accords sufficiently well with the Meerut rate of $1\frac{1}{2}$ rupee per acre, the assumed average for the whole canal.

30. With regard to the Committee's remarks on *economy in the use of water and on water-meters* (paras. 153 to 167), I annex (as Appendix D.) copy of paras. 12 to 15 of "General Remarks" in my Revenue report for 1863-64, from which it may be seen that a fall, of say one foot perpendicular, or at all events a mean velocity of not less than two-and-a-half feet per second, is required in a channel, in order that its discharge may be registered, or that an effective module may be constructed to equalize its discharge. For localities where a fall can be obtained there are many kinds of modules which would answer;—one by Colonel A. G. Goodwyn, on the principle of the conical vertical stopper; one of my own, of 1851, on the principle of the balanced sluice; one by the late Colonel Patrick Stewart, proposed to me in 1856, on the principle of the floating siphon; another on the same principle, proposed by Major H. Hyde in 1862; Mr. Faulkener's on the same principle, which he has just patented, but inadvertently I imagine, as it is one of the oldest hydraulic inventions of which a record has come down to us, being described and figured in the "Spiritalia" of Hero of Alexandria, who flourished in the time of the Ptolemies. Mr. Faulkener has also patented several very ingenious modifications of the balanced shutter, and of the floating head; but all these mo-

dules are more or less complicated, requiring floats to work them, or at least to assist their action. The most promising module I have yet seen is one lately patented by Lieutenant W. J. Carroll, R.E., in which the impulsive force of the water issuing from an orifice is made to regulate its own discharge. A module on this principle is in hand, and will shortly be set up and experimented on, as well as some of the simpler modules of Mr. Faulkener's invention.

It may be observed, however, with reference to the Committee's remarks, that even under the system of water-rate charged on the area of land irrigated, considrable inducement is afforded to the cultivator to make the most economical use of the water issued to him. For the supply of water being limited, and the area of land requiring water being practically unlimited, he naturally tries to make the water go as far as he can. The steady and rapid increase of the irrigating duty rate (area irrigated per cubic foot per second) of water supplied by the Ganges canal, shows that vigorous efforts are being made to economize water, and to employ it to proper advantage. In the Etawah division, the Executive Engineer has actually been obliged to warn some of the cultivators not to attempt too much at first. The great secret of economy in irrigation is that the land should be properly levelled, and prepared, in small plots, to receive the water; in order that one end of a field may not be submerged, while the other end remains parched and the centre portion alone produces a fair crop. This preparation of the land the cultivators always postpone as long as they can, but the late enhancement of water-rates will compel them to attend to it more carefully. As soon as the land under canal irrigation is as carefully prepared to receive the water as the plot round a well, the irrigating duty rate will approximate to the standard for well irrigation, which I calculated at 400 acres per cubic foot per second. This is the result of actual observation on wells in the Punjab. The Committee have arrived at a similar standard (414 acres) in another way.

31. With regard to the Committee's remarks *on the comparative financial results of irrigation works in the Madras Presidency and in the North-Western Provinces*, and to the valuable appendices thereon by Colonels Lawford and Anderson, it may also be noted that, in the financial returns of Northern India, irrigation works are, by order of Government, debited with interest at 5 per cent. per annum on their capital expenditure. On the other hand, Madras works are debited with interest at 4 per cent. only, I do not know the cause of this difference, but the result tells heavily against the works of Northern India. I have represented this matter in a separate report, No. 170c., of the 10th instant.

32. As regards the *probable cost* of the works necessary to enable the Ganges canal to carry with safety the full supply which may be permanently available at Hurdwar, I should be inclined to let Major Crofton's estimate stand; for any saving effected in one direction will probably be expended in another. The quantity of earthwork, for instance, may be less than he estimated, but it has been ascertained from actual work, that his rate of 2 rupees per 1,000 cubic feet is too low, and that the work will cost 2½ rupees, working as economically as possible. If the work is to be pushed on quickly, the rate must be raised to 3 rupees per 1,000 cubic feet.

33. In conclusion, and to recapitulate, I recommend that Major Crofton's project be adhered to in principle, retaining the slopes for water's surface laid down in

his Appendix B.; that the manufacture and collection of materials as required for the works projected by him (with the exception of extra arches to bridges, and with the addition of extra tail protection to those works) be gone on with; that a sufficiency of material to provide for all possible requirements in repair be landed at sites of existing works with the least possible delay; that the left bank of the canal with 5-feet towing path, be sloped off and completed wherever practicable; that the right bank above Roorkee be sloped off and completed with the 15-feet roadway; and that observations be carefully made to ascertain the minimum discharge of the Ganges, Jumna, and Hindun rivers, as well their discharges for some time before and after the period of minimum discharge. By the time all the materials are ready, we shall probably have obtained the requisite information on this head. Meanwhile opportunity should be taken in every ordinary closure to experiment on the adaptation of existing works to carry a larger supply of water, and generally on the execution of work without a prolonged closure;—the staunching of the Solani aqueduct inclusive.

I recommend that the survey for a detailed project for the new canal from the Jumna at Alee be at once started, and that for the head-works at Hurdwar completed, and that both projects be prepared as soon as possible. Also the projects for remodeling the Cawnpore and Etawah branches. The Futtehgurh branch must wait for the decision of the question of supply of water available. I can see no reason why, with Executive Engineers available for both, the work of remodeling the Ganges canal should be postponed for the Jumna canal project, or *vice versâ*. And this opinion I gave the Committee, on being asked for it during their discussion of the question.

J. H. DYAS, Lieut.-Col., R.E.,
Chief Engineer, Irrigation Works, N. W. P.

APPENDIX A.

Demi-Official Report on the State of the Ganges Canal Works, as observed in the closure of August, 1866, *by Major H. A. Brownlow, R.E.—Dated Roorkee, 23rd August,* 1866.

Between *Myapore* and *Roorkee,* the damage to masonry is quite insignificant.

Below the *Myapore Regulator* the bed has been slightly scoured (maximum depth 2 feet, at 20 feet from bridge, against 1½ foot in 1864); but at 80 feet from bridge, a heavy shingle and silt deposit has taken place, as was to be expected (3 feet above bed, against 2 feet in 1864.)

Below *Jowalapoor Bridge,* a cutting of maximum depth of 8 feet in 1864, has silted up to 3 feet, and has moved some 50 feet further away from bridge.

Below *Raneepore Superpassage,* maximum depth of cutting 9½ feet against 10½ in 1864, at same distance, 60 feet, from end of crib-work.

At *Bahadoorabad Fall (upper),* maximum depth 23½ feet, at 80 feet from end of pile-work; against 21 feet, at 60 feet, in 1864.

At *Bahadoorabad Fall (lower),* maximum depth 29½ feet, at 100 feet from crib-work; against 12 feet, at 20 feet, in 1864.

At *Puttree Superpassage,* maximum depth 15½ feet, at 60 feet from crib-work; against 11½ feet, at 20 feet, in 1864.

At *Roorkee Bridge,* maximum depth 6 feet, at 150 feet from flooring; against 8 feet, at 40 feet, in 1864.

At *Asufnugger Fall,* maximum depth 22½ feet at 106 feet from crib-work; against 31½ feet, at 70 feet, in 1864.

At *Munglour Bridge,* maximum depth 15½ feet, at 160 feet from flooring; against 17½ feet, at 140 feet, in 1864.

At *Liburheree Bridge,* maximum depth 8 feet, at 120 feet from flooring; against 15½ feet, at 100 feet, in 1864.

At *Mahmoodpoor Fall,* maximum depth 25½ feet, at 180 feet from crib-work; against 30½ feet, at 200 feet, in 1864.

At *Dhumat Bridge,* maximum depth 11½ feet, at 180 feet from flooring; against 15 feet, at 70 feet, in 1864.

At *Nirgajnee Fall,* a small hole, 50 by 30 feet, and 4 feet deep, close to the crib-work, has remained unaltered since 1864.

At *Belra Bridge,* maximum depth 15 feet, at 90 feet from flooring; against 26½ feet, at 80 feet, in 1864.

At *Jowlee Fall,* maximum depth 25½ feet at 80 feet from crib-work; against 22½ feet, at 50 feet, in 1864.

Between *Roorkee* and *Jowlee,* the damage to masonry works consisted of the scouring out of a couple of holes in the ogee of the centre bay of the Mahmoodpoor Fall (these were not more than 2 feet deep, and were easily repaired) and of the ripping off of about 1,500 square feet of the upper layer of flooring in centre bay of Nirgajnee Fall immediately below ogee.

In the flooring of the *Jowlee Fall,* a subsidence, which took place in August, 1864, had remained unaltered. A space measuring 54 by 32 feet in the right bay had sunk 7½ feet on the average; and

another space, measuring about 32 by 22 feet, in the centre bay had sunk 4 feet. A few stones were knocked out of the floor in other places.

In the *Meerut Division* (below Jowlee) the injury to masonry works has been confined to the stripping off of brick-on-edge flooring in places at the Chitowrah, Sulawur, and Bholah Falls, and it is very trifling in extent.

In the *Allygurh Division*, the only damage which had taken place since 1864, was to the flooring of the second bay from the right of the Somera Fall. The upper layer of brick-on-edge was washed clean out, exposing the upper surface of the *kunkur* foundations.

No damage of any consequence in the other Divisions.

The repairs carried out have been,—careful filling of all holes in masonry works, the upper layer being replaced by Delhi stone in all cases, except on ogees, where brick-on-edge had to be used; thorough renewal and extension of stone or brick-slag aprons above and below all masonry works; filling in trees (dug out by the roots, and heavily weighted by stones attached to butts) into the deeper holes wherever they existed.

The Delhi stones in flooring have been laid with their dressed faces downwards, as it has been observed that all displaced stones had finally rested on the flooring in that position.

(Signed) H. A. BROWNLOW, MAJOR, R.E.,

Supdg. Engr., 1st Circle, Irrigation Works, N.W. P.

APPENDIX B.

Memorandum on the necessity for Permanent Head Works at Hurdwar.

THE Ganges canal Committee have recorded their opinion, (para. 124 of Report,) that if the supply at present required by the canal at Myapore, or about 5,000 cubic feet per second, were to be the maximum one at that point, Permanent Head Works would not be necessary.

2. This opinion is enforced by the following arguments :—

1*st.*—That the expense attendant on the annual construction of temporary weirs (*bunds*) has not increased to the extent that was anticipated.

2*nd.*—That the annual saving due to the substitution of permanent for temporary head works would be only a little over Rs. 10,000; and that even if this saving were to increase to Rs. 15,000, it would represent a capital of but three lakhs of rupees, for which a permanent dam or weir could not be built.

3*rd.*—That although there is some risk of the river falling so low during the rainy season as to render the re-construction of the temporary bunds necessary before the usual time for undertaking the work, as happened in 1860-61; yet with the more extended experience now possessed by the Executive Officers, and the good management that may be expected, there should be no difficulty in feeding the canal during the monsoon.

3. I cannot think that the Committee have fully appreciated the importance of the question at issue.

The arguments as to expense may be disposed of in a very few words.

No doubt, if the canal could be provided with a permanent head for a certain outlay, the interest on which represented or fell short of the annual expenditure on the perishable structures now employed, the fact might be brought forward as a very good reason for incurring the capital outlay.

But the converse by no means holds good; it cannot, as I conceive, be asserted, speaking within bounds, that because the temporary works are maintained at an annual expense which is less than the interest on the capital sum required to build a permanent weir, therefore there is any reason whatever why the latter should not be preferred. The decision of the question will not rest on money considerations, if it can be shown that interests are involved which cannot be gauged by rupees.

4. The point really to be determined is this,—does the well-being of the canal, and of those who are dependent on it for their very existence, demand that permanent head works should replace the present temporary ones ?

If the reply be in the affirmative, I submit that it is a matter of comparatively very little importance whether the annual expenditure now incurred represents interest at 2½ or at 5 per cent., on the capital to be sunk on permanent works.

5. Now I base my opinion that a permanent head is a vital necessity for the Ganges canal on the very experiences which the Committee interpret the other way. These experiences are derived, *firstly*, from the famine year 1860-61; and *secondly*, from the ordinary requirements of the canal.

6. As regards the famine year, the Committee say that the failure of the canal during that period has been exaggerated. In what form this exaggeration has appeared, or who is responsible for it, is not stated. But the Committee proceed, apparently, to prove the fact of the exaggeration as follows :—

" For a great part of that year, the whole supply of the river was turned into the canal, and the Revenue returns were more than double those of the previous year; but the fact of 73 acres only having been irrigated per cubic foot of water admitted into the canal, while at present upwards of

140 are irrigated by the same quantity, indicates that the great want of the famine year, so far as the canal was concerned, was the means of distributing the water. The rajbuhas were then in their infancy, and without a proper proportion of them, it would have been useless to increase the supply from the river."

7. This extract from their Report leads me to suppose that the Committee have not clearly comprehended the difficulties that were encountered during the famine year. It is possible that the whole supply of the river,—minus leakage, no inconsiderable item of loss in crib and boulder bunds,—was for part of the year turned into the canal. But the canal supply during the rainy season at all events was very inconstant, as is shown by the canal gauge register at Myapore and Roorkee, copy of which, for the months of June, July, August and September, 1860, is appended to this Note. And this inconstancy was obviously not due, *directly* at least, to the fluctuating volume of the river, but to the defective head arrangements on the canal itself. *Indirectly*, the varying level of the river's supply had a very serious effect, which a masonry weir would have warded off. The river would suddenly rise with one of the spasmodic falls of rain that used to occur that year, and as suddenly fall after more or less injuring all the temporary bunds. The consequence was that the canal supply fell, too, simply because the head works had no proper control over the river.

8. I have a distinct recollection of the trouble and anxiety which the maintenance of the canal supply cost us that year, after the bunds were breached, about the middle of June, for the first time in the season, and this recollection is amply corroborated by a private journal kept at the time. I will quote only one entry. On the 25th September, I went up to Myapore with the late Colonel Turnbull, and, after a careful inspection of the head works, I recorded our joint opinion as follows:—

"The canal supply is now terribly low, although water is much wanted. It becomes a serious question, which we must solve as soon as possible, what arrangements are to be made for maintaining the canal head; it is clear that the system hitherto followed is useless, in seasons like the present, for securing a full supply, and that it is even incapable of giving any regular supply at all."

Whatever value such an opinion may possess on other grounds, it has at least the merit of having been formed on the spot, after a tolerably intimate acquaintance with the canal head works during the most trying year of their existence, and is not due to any effort of memory.

I do not suppose that any one who witnessed the almost daily struggle that went on for upwards of three months in keeping up the canal supply, would call it exaggeration to say that all the losses and anxieties to which the cultivators irrigating from the Ganges canal were subjected during that period were attributable solely to the absence of proper means of controlling the river.

It is scarcely needful to point out that it is not sufficient, in order to meet the requirements of the canal, to secure *at intervals* its full supply. There should *always* be a full supply, so long as water is in demand, and for this purpose the head works should be capable, if necessary, of abstracting (practically) every drop from the channel of the river.

It has been well said that "the essence of all irrigation projects is certainty and continuity of supply."

9. But the Committee seem to imply that whatever difficulties beset the management of the canal heads in 1860, the experience now possessed by the Executive Officer and his Establishment would bring about a different issue, if a similar year recurred.

I feel sure that I shall not be suspected of depreciating the merits of the able and energetic Officer now in charge of the Northern Division of the canal if I express my deliberate belief that, so far as the main results are concerned, they would not be very different now from what were attained in 1860, if the same circumstances were to arise. Making every allowance for the additional experience acquired during the last six years, the fact remains that no human care or oversight can prevent temporary bunds from being breached by floods; and if, as in 1860, the river alternately rises and falls, the bunds must be frequently repaired, and on each such occasion, there must be more or less interruption to irrigation. The utmost, therefore, that the Committee can make of their argument, is, that at the present time the interruptions would be of less duration than they were in 1860.

10. I may here advert to what seems to me an error of deduction in para. 126 of the Committee's Report. The statement that one cubic foot of canal water now irrigates 140 acres, while in

1860 the same quantity covered only 73 acres, does not merely indicate that "the great want of the famine year, so far as the canal was concerned, was the means of distributing water." Of course these means were then very defective, and there can be no doubt that, had they been more ample, the same maximum supply in the canal would have sufficed; in other words, that a large proportion of the water taken in at the head was wasted. But it is to be borne in mind that this waste was necessary to admit of the rajbuhas that then existed, doing their duty. The canal, was pledged to provide for a certain area of irrigation; for this area rajbuhas and their minor distributing channels were ready. But the sills of rajbuha heads are, in the upper parts of the canal, laid considerably above canal bed. So also the sills of rajbuha outlets (*Kolabahs*) are above rajbuha beds. For the canal, then, to give its rajbuhas, and these to yield to their minor channels a proper supply, it must happen, when irrigation arrangements are not fully developed, that much more water is required than is actually expended with profit. And if this waste be not incurred, all irrigation over large tracts will cease. Accordingly it is incorrect to assume that, because the acreage of actual irrigation seemed to require in 1860, a canal supply only one-half of that now utilized, therefore half the present supply would have sufficed in that year.

11. A year like 1860, however, is an exceptional occurrence, and although I contend that to provide satisfactorily for the demand of such a year, the canal should have permanent head works, I consider that the necessity for these works is far more general.

It frequently happens that during the months of March, April, and May, floods severely injure the temporary bunds. These are of course at once repaired, but it is impossible to avoid interruption to irrigation. Thus in 1861, the Government, North Western Provinces, reported to the Government of India that "the head bunds on the Ganges canal were much damaged by an unexpected flood on the 17th May, the water in the canal being reduced to 5 feet." The Deputy Superintendent General of Irrigation, North Western Provinces, wrote on the 1st June following that, "the breach in the Bheemgoda bund, caused by the flood of the 17th ultimo, has been widened by subsequent floods. * * * In all probability the rain which has fallen yesterday and to-day will so swell the river, that the total destruction of the bunds will be effected, although a month earlier than it is looked for in ordinary years."

The records of the time afford ample proof that this occurrence caused the most serious anxiety, lest the misfortunes of the previous year should recur, and it was not until the 17th June that the setting in of a most favorable rainy season removed all fears of a continuance of drought. Such accidents to the head bunds are of almost yearly occurrence; their effects are not always equally disastrous, but they undoubtedly contribute to keep up that distrust of the canal, which has done much to oppose its progress.

12. There is an argument in favor of Permanent Head Works, which the Committee notice, but which, I cannot help considering, they pass over too lightly. It is that the maintenance of temporary weirs during the rains, when such a proceeding is necessary, involves exposure which it is very desirable to avoid, for the sake of both Europeans and Natives. This argument is a strong one as regards the members of the canal Establishment; but it is their duty to incur such risks, and they cheerfully fulfil it. How much stonger is it where workpeople are concerned!

It is useless to deny that labor employed on the canal head works during the unhealthy season of the rains is not in all respects voluntary. Allow full liberty of action to the laborers, offering even increased rates of daily wages, and how would the head bunds be repaired? No matter what the mode of persuasion adopted be, it may not amount to positive force; but such as it is, I hold that even at the risk of a capital outlay, which shall be equivalent to an annual expenditure double of the present one, the necessity for such a system should be removed at once by abolishing all the temporary works, and replacing them by permanent structures.

NYNEE TAL,
The 29th October, 1866.

W. E. MORTON, COLONEL,
Secretary to Govt., N. W. Provinces, P. W. D.

Register of Water at Myapore and Roorkee.

Date.	June, 1860.		July, 1860.		August, 1860.		September, 1860.	
	Myapore.	Roorkee.	Myapore.	Roorkee.	Myapore.	Roorkee.	Myapore.	Roorkee.
1	8·17	5·84	6·08	3·42	7 83	4·84	6·00	3·84
2	8·33	5·84	6·75	3·84	7·33	5·08	5·92	3·00
3	8 17	6·00	6·08	3·58	8·00	6·00	5·67	3·00
4	8·00	5·50	6·17	3·84	8·00	5·84	5·67	3·00
5	7·33	4·50	6·25	3·84	7·25	5·34	5·25	2·75
6	7·33	4·92	6·67	4·25	7·42	5·50	5·08	2·25
7	7·42	4·75	7·00	4·84	7·50	5·33	5·00	2·16
8	7·83	5·08	6·79	4·33	7·58	6·10	5·00	2·33
9	8·25	5·84	6·87	4·42	8·00	5·84	5·50	2·75
10	8·33	5·92	6·54	3·75	8·00	5·92	6·00	3·25
11	8·37	6·08	6·62	4·08	8·00	5·40	6·17	3·58
12	7·33	5·58	6·67	4·25	8·00	6·00	6·42	4·00
13	8·00	5·08	7·17	4·84	9·00	..	6·54	4·42
14	7·92	5·42	7·50	5·08	9·50	..	6·92	4·92
15	7·54	5·00	7·58	5·58	9·67	..	6·75	4·92
16	7·08	4·00	8·25	6·33	9·33	..	6·62	4·16
17	6·70	3·33	8·00	5·50	8·50	..	6·67	4·50
18	6·80	3·33	7·88	5·50	9·00	..	6·33	3·92
19	6·92	3·92	7·58	5·08	9·00	..	6·25	3·92
20	7·33	4·33	6·50	5·25	6·25	3·92	5·75	3·08
21	8·80	4·84	6·67	5·00	7·42	5·00	5·50	2·75
22	8·80	6·00	8·00	5·84	8·00	5·84	5·29	2·67
23	8·25	6·08	7·58	5·75	8·67	6·00	5·29	2·67
24	8·25	6·08	8·00	5·84	8·67	6·00	5·50	2·75
25	8·25	6·08	8·00	5·84	8·00	6·00	5·50	2·75
26	8·00	5·58	8·00	6·00	9·50	6·00	5·58	2·75
27	7·50	4·84	8·00	5·92	7·33	5·17	5·67	2·84
28	6·00	3·50	7·54	5·84	7·17	4·92	5·67	2·92
29	5·33	2·58	8·00	6·00	6·83	4·58	5·67	2·92
30	5·50	2·84	8·08	6·00	6·42	4·23	5·67	2·75
31	..	..	9·00	6·00	7·17	3·92	..	..
Average,... ...	7·59	4·71	7·28	5·02	8·01	5·36	5·83	3·25

Executive Engineer's Office, Northern Division, Ganges Canal.
Dated Roorkee, the 24th October, 1866.

J. G. FORBES, Captain, R.E.,
Executive Engineer, Northern Division, Ganges Canal.

APPENDIX C.

Memorandum on the method of estimating the amount of enhancement of Land Revenue due to Irrigation Works, illustrated by a Statement of enhancement in the Seharanpore district, by H. Le Poer Wynne, Esquire, C.S., Settlement Assistant.—Dated Seharanpore, the 21st September, 1866.

HAVING, for purposes of assessing the canal irrigated tracts and the neighbourhood, divided the villages of each pergunnah into two groups:—

1*st.*—Those irrigated by the canal.

2*nd.*—Those not irrigated by the canal, but of similar natural qualities; and having now finally worked out the assessment of both, I am able to give a far more accurate estimate than I prepared before.

The method adopted is as follows:—

By applying to the cultivated area of the irrigated tracts (Column 2) the rent-rate adopted for the corresponding non-irrigated tract (Column 12), the rental which the former would bear if there were no irrigation from the canal, is obtained (Column 7). Multiply this by 0·55 to get the *jumma* (Column 8). Deduct the product from the *jumma* actually assessed on existing assets (including those due to canal (Column 6), and the remainder (Column 9) shows the increase due to the canal). The figures given in Columns 4 and 10 are of use, as showing what the per-centage of increase is, where such and such a proportion of the total area is irrigated.

I may mention that I have omitted from this Table the canal-irrigated groups of Roorkee and Jowalapore, and also Deobund V., in which canal irrigation has been but little extended, and in the two former of which, owing to the usually plentiful fall of rain, canal irrigation is of comparatively little advantage. These groups entered into my former calculations, and lowered the average of the whole Zillah.

(Signed) H. LE POER WYNNE,
Settlement Assistant.

[*See Statement overleaf.*]

TABLE *showing the amount of increase of Jumma due to Canal Irrigation in certain tracts of Zillah Seharunpore.*

GROUP.	Total cultivated Area.	Area irrigated by Canal.	Per-centage of Canal Irrigation.	ACTUAL		IF NOT IRRIGATED		Increase due to Canal.	Per-centage on *jumma* of Total Area.	REMARKS.		Rent-rate per Acre of cultivation.
				Rental.	Jumma, at Rs. 55 per cent.	Rental.	Jumma, at Rs. 55 per cent.					
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.		12
(i) Groups irrigated from the Canal.											*(ii) Groups not irrigated from Canal.*	R. A. P.
Sooltanpoor (*i*), ..	10,001	3,792	37·8	32,339	17,786	28,834	15,858	1,928	12·2	Irrigated from the Eastern Jumna canal. A. Irrigation from wells could be so freely practised in this group that Canal Irrigation is of (comparatively) little advantage.	Sirsawah (*ii*), ..	2 14 1
Sirsawah (*i*), ..	9,383	3,294	35·1	30,898	16,993	27,025	14,863	2,130	14·3		Nukoor (*ii*), ..	2 14 1
Nukoor (*i*), A. ..	9,218	4,148	45·0	29,834	16,408	27,030	14,866	1,542	10·3			
Gungoh (*i*), B. ..	9,383	6,392	68·1	38,971	21,433	23,262	12,794	8,639	67·5	B. This group has received I consider the maximum amount of Canal Irrigation. Much of the land is irrigated for both rice and wheat, autumn and spring crops.	Gungoh (*ii*),	2 7 8
Rampore, C. ..	63,006	32,758	52·0	2,30,943	1,27,018	1,56,202	85,911	41,107	50·6	C. The above remark applies to a large portion of this group also.		
Deobund (*i*), ..	13,860	2,560	18·4	41,553	22,854	35,300	19,415	3,439	17·7		Deobuud (*ii*),..	2 8 9
Nugul (*ii*), ..	2,081	688	33·0	6,851	3,768	5,809	3,194	574	17·9	Irrigated from the Ganges canal.	Nugul (*i*), ..	2 11 4
Munglour (*i*), including Tansipore, ..	35,220	10,996	31·2	1,14,863	63,174	98,323	54,077	9,097	16·7		Bhugwanpore(*i*),	2 14 1
Total, ..	1,52,152	64,628	42·4	5,26,252	2,89,434	4,01,785	2,20,978	68,456	30·9		AVERAGE ..	2 12 8

SEHARUNPORE,
The 21st September, 1866.

(Signed) H. LE POER WYNNE,
Settlement Assistant.

APPENDIX D.

Extract (paragraphs 12 *to* 15*) of "General remarks" in the Annual Revenue Report on Irrigation Works in the North-Western Provinces, for the year* 1863-64, *by Lieut.-Colonel J. H. Dyas, R.E., Chief Engineer of Irrigation Works, North-Western Provinces.*

12. It has lately been asked by Government why the system of rating per cubic foot of discharge is possible in the Doon, and not elsewhere; I shall endeavor to explain. In order to measure the discharge throughout the year of any stream of water, we must either set up a machine technically called a module) at the head of the water-course, which shall make the discharge through it constant, in spite of all possible fluctuations of the height of water in the canal which supplies the the water-course, or which shall register the ever-varying quantity of water passing through it, or else we must keep a daily register of the height of water, by inspection of a water-gauge fixed in some permanent part of the water-course at, or not far from, its head; when by means of a series of observations on sectional area and velocity of current with different heights of water on the gauge, we are enabled to compute a "Table of discharges" corresponding with all possible readings on the gauge. Combination of the information given in this Table, with that afforded by the daily register of the gauge, will then give the discharge for the time during which the gauge was registered.

13. Now, whether we make the discharge constant by means of suitable machinery, or whether we measure the varying discharge by a self-acting water-meter, or by simply registering daily the height of water on a gauge, one thing is essential, viz., a velocity of current sufficient under all fluctuations to maintain in its integrity that point of the channel, where the machine or the gauge is fixed, together with such a length of channel below that point, that the normal velocity of the current for each varying height of water shall in no way be interfered with. If the velocity of the current is not at all times sufficiently rapid to carry forward the silt held in suspension in the water, silt must be deposited, and the machine will be clogged, and the section of the channel will be so altered, that the readings of the height of water on the gauge will no longer denote for us the corresponding discharges as given in the Table; nor will a register of the depth of silt deposited get us over this practical difficulty, because silt is not always deposited in the same way, and the deposit is not confined to a layer uniformly spread over the bed of the channel, the sides also coming in for a considerable share.

14. In short, what is wanted, in order to measure the discharge in a water-course subject to fluctuations, is a clear fall, of say one (1) foot under all circumstances. With this fall we can measure; without it, we cannot; that is to say, in earthen channels. For, supposing we had in an earthen channel, at the lowest irrigating level of the water, a velocity of current sufficient to prevent deposit of silt, a very moderate rise of the water would give an increased velocity, which would soon be too much for the earthen channel. In a masonry channel of course this would not happen, but masonry channels are rare.

15. In the Doon, high velocities in masonry channels and falls in earthen ones can be had, and falls can be had also in the higher portions of the canals in the plains. Wherever they can be had, I propose to carry out the system of contract rating per cubic foot of water issued. Lower down in the plains it is not always possible to get slope enough even for the rajbuhas, and no falls can be had, so that we must be content with a system of contract based on the ascertained capabilities of water-courses; or, in other words, on a knowledge of the areas irrigated by them, say for the five (5) years preceding the contract.

(Signed) J. H. DYAS, Lieut.-Col., R.E.,
Chief Engr., Irrign. Works, N. W. P.

Observations by the Hon'ble the Lieutenant-Governor, North-Western Provinces.

THE recommendations of the Chief Engineer, recapitulated in the 33rd paragraph of his remarks, are approved of. The report of the Committee on the Ganges Canal is most valuable. The wish of the Supreme Government, to obtain a really impartial Report on many vexed questions of great importance in connection with irrigation, has, in His Honor's opinion, been completely attained.

2. The thanks of this Government are conveyed to the President and the Members of the Committee, with an expression of great regret that Colonel Lawford's health should have been so seriously affected by exposure in the execution of arduous duty at such an inclement season. Major Crofton is also thanked for his valuable assistance rendered to the Committee.

3. The Committee's Report was not received till the 24th July last, and the Chief Engineer has explained that, in so grave a matter, he had to take time for consideration, and that he wished particularly to be able to annex the official detailed Reports on the actual state of the Ganges Canal Works, as exhibited during the closure in August.

Dated Nynee Tal, the 22nd October, 1866.

ORDER.—Ordered that a copy of the foregoing be forwarded to the Secretary to the Government of India, Public Works Department, with reference to his letter, No. 789c., dated 29th August last, as also to the Officers marginally noted.

Ganges Canal Committee.
- Colonel E. Lawford, R.E., Chief Engineer, Madras, — *President*
- Lieutenant-Colonel J. C. Anderson, R.E., Consulting Engineer, Government of Madras, Railway Department. — *Members*
- Lieutenant-Colonel Fife, R.E., Bombay Establishment. — *Members*
- Mr. G. Sibley, C.E., Chief Engineer, East Indian Railway, North-Western Provinces. — *Members*
- Mr. H. Leonard, C.E., Superintending Engineer, Bengal. — *Members*
- Superintending Engineer, 1st Circle, Irrigation Works. — *Members*
- Ditto, 2nd Circle, Irrigation Works. — *Members*
- Chief Engineer, Irrigation Works, Punjab. — *Members*

By order, &c.,

J. H. DYAS, *Lieut.-Col., R.E.,*
Under-Secy. to Govt., N. W. P.,
Public Works Dept.

Memorandum by MAJOR J. CROFTON, R.E., *Chief Engineer, Irrigation Works, Punjab, on alterations in the project for remodeling the Ganges Canal, proposed in paras.* 107 *to* 111 *of the Report of the Committee.*

THE alterations recommended by the Committee in the scheme for remodeling the main line of the Ganges canal, as I gather from paras 107 to 111 of their report, are as follow :—

1*st.* The earthen channel generally to be left as it is, not widened to give a shallower water section as proposed.

2*nd.* Above the Rutmoo, the velocity of current to be reduced to the standard by raising the crests of the falls.

3*rd.* From the Rutmoo to Roorkee the velocity due to the existing declivity and section to be retained; the floorings of the Rutmoo, Peeran Kulliar and Muhewur bridges to be secured, and the bed of the earthen aqueduct across the Solanee valley pitched with some hard material.

4*th.* The new fall at Roorkee to be dispensed with; the crest of the Asuffnuggur falls being raised to throw a backwater as far as Roorkee—at least I gather that the backwater is not intended to extend further, as objection is taken to a greater depth than 10 feet passing over the aqueduct, and this is the depth at full supply with the present declivity.

5*th.* Below Asuffnuggur the new falls to be built, and the old ones rectified, as proposed; but the additional arch to the eight bridges between Roorkee and the Futtehgurh branch head to be omitted.

2. There is no objection raised if I understand the report aright, to any of the new works or alterations projected below the Futtehgurh branch head, except the widening of the excavated channel. As nothing is mentioned regarding the projected alterations to the falls and bridges between the Rutmoo and Jowalapoor bridge, I presume they are considered to be indispensable, and that the velocities of current with a full supply, determined on as safe in projecting those alterations, should be retained.

3. The estimate for the excavation from the heads to the Futtehgurh branch bifurcation, is as follows :—

	Cubic feet.	Rupees.
From heads to projected new fall, close below Roorkee bridge, ...	38,972,452	77,945
Thence to Futtehgurh branch head, ...	1,68,474,950	3,36,950

I have not the cross sections of the channel as it exists, from which the excavation was calculated, by me to refer to; but, if I recollect aright, a very large proportion of the excavation above Roorkee is due to the sloping of the sides in deep cutting to prevent the falling in of the superincumbent earth where the erosive

action of the current has cut them away to a vertical section, as well as to the cutting down and re-forming of the tow-path on the left bank, mentioned in the latter part of the 45th para. of the report.

The sloping of the sides, is, I think, a necessity under any circumstances, and the excavation for a tow-path on one bank at least is required if the navigation here is considered to be a matter of importance.

The alterations projected to the bottom width of the channel as originally excavated were as follow :—

	Miles.	Feet.	
From	1	4,347	Unaltered.
To	5	648	
From	5	648	Widened 5 feet.
To	6	5,111	
From	6	5,111	Unaltered.
To	9	3,930	
From	9	3,930	Widened 12 feet.
To	12	4,179	

The channel has, however, in general widened considerably, as well as deepened, since it was first excavated; and the existing mean width of the water section in most places will probably be found to be nearly, if not quite, equal to that contemplated in the remodeling.

4. If the drop and grating at the Khunkhul bridge be dispensed with, it will be necessary to add somewhat to the down-stream talus of boulders to secure the foundations of the bridge.

How the change in declivity is to be made a gradual one, as recommended in the 8th para. of the Committee's report, I do not understand; there is already a drop at the bridge, and the bed has been channelled out below on a tolerably even slope down to the Ranipoor falls.

The effect of holding up the water to the height (13 feet) at those falls, as projected in the remodeling scheme, will be to raise the surface of the stream for some distance above the Khunkhul bridge, and so to a certain extent lessen the velocity of the current there; but if provision be not made to concentrate the action at the bridge, erosion on bed and sides will undoubtedly take place for some distance below the point of change from the smaller to the larger section.

5. In para. 109, the Committee express their opinion that the channel from the Rutmoo to Roorkee will answer as it is, *i. e.*, carry the full supply of water safely, with the calculated velocity of 4 feet per second, if the bed of the earthen embankment across the Solanee be pitched, and the floorings of the Rutmoo, Peeran Kulliar and Muhewur bridges be secured, they consider that the increase to the depth of water passing over the masonry aqueduct, of from 10 to 13 feet, is hazardous, without making special provision for the increased weight, which would be costly. On a careful reconsideration of the question, I must say that I do not myself see the slightest cause for apprehension of any danger from this cause; the increase to the depth of water, and therefore to the weight over the arches, is less than one-third of that originally calculated on. The dimensions of the work where it is exposed to the greatest strain are more than sufficient to sustain a much grea-

ter pressure than even a much larger addition to the weight would bring on it. The dimensions of each arch are—

Span,	= 50	feet.
Total rise,	= 8	„
Thickness of arch at crown,	= 5	„

The bed of the water channel being 1 foot above the extrados of the arch.

The curve of the intrados is elliptical, but the voussoirs are radiated from one centre in an arc of 60 degrees.

The percolation through the arches alluded to has never ceased from the first; though, as stated in the 8th para. of the report on the remodeling, it has sensibly decreased; the true remedy for the evil is undoubtedly a water-tight covering, and this once properly applied, would be proof against a very much greater increase of superincumbent pressure than that in question.

It is also to be borne in mind that the velocity of current with the increased depth of water would be reduced by one-fourth, *i. e.*, from 4 to 3 feet per second.

The covering of puddled clay estimated for was to be protected from the scour of the current above, by a layer of brick-on-edge, which even if of very inferior materials and workmanship, I need hardly say, can withstand the effect of a very much higher velocity than 4 feet a second.

6. If the velocity of current at full supply below the Roorkee bridge is to be reduced generally to the standard assumed in the remodeling project, viz., 2·7 feet per second; and if this is to be effected above Asuffnuggur without the projected fall at Roorkee, and the widening of the channel, simply by raising the surface at the Asuffnuggur falls, without however permitting an increase to the depth of water on the Roorkee bridge flooring, the erosive action must continue for some distance below the bridge, and with a full supply will undoubtedly increase, wherever a change of velocity takes place, even though it be from a higher to a lower, the boils and eddies consequent thereon will without doubt cause erosion in soil of so light a nature.

7. If the canal be not widened as proposed between Roorkee and the Futtehgurh branch bifurcation, and the maximum velocity of current which it is considered safe to allow for a permanency be assumed, as in the remodeling scheme, at 2·7 feet per second, and it we suppose that the channel generally has been enlarged to the extent shown in the section above the Guneshpoor bridge, and below the Jowlee falls (*vide* diagrams at page 6 of the report); that is to a bottom width of 150 feet with side slopes of 1 in $1\frac{1}{2}$; the depth of water with the full supply of 6,750 cubic feet per second will be about 14·5 feet, and the declivity of surface 1 in 13,500 (instead of a depth of 11·3, with surface slope of 1 in 11,000).

The difference between the full supply depth on the flooring of the Roorkee bridge and that in the channel below where the current is "in train" will therefore be (14·5 – 10 =) 4·5 feet; and to this extent, it will be seen from the longitudinal section, the channel below the bridge has already been deepened; the section also shows that the remodeled bed follows almost exactly the line of the deepest channelling down to the Asuffnuggur falls. If the new bed be depressed, as projected in the remodeling, 2 feet below the present crest of the Asuffnuggur falls, the water will stand (14·5 – 2 =) 12·5 above the crest there, the distance between

Roorkee bridge and the falls being 21,202 feet, and the slope of surface being 1 in 13,500, the total rise up to the former will be 1·57 feet, from which we obtain—

Reduced level of bed at Asuffnuggur, ...	267·65
„ surface of water at Asuffnuggur,..	253·15
„ „ at Roorkee, ...	251·58

Now the

Reduced level of flooring of Roorkee bridge, being ..	261·25
„ of surface of water on flooring depth being 10 feet,	251·25

there will be thus a fall in the surface at Roorkee bridge of (251·58 – 251·25 =) 0·33, which it would be necessary to obviate by raising the surface at the falls; the total height, however, from the crest to the crowns of the arches is but 11·35 feet, so that the water without the raising would stand (12·5 – 11·35 =) 1·15 feet above the level of the crowns; it would, therefore, I think, be necessary to raise the whole of the arches and roadway of the falls, which was obviated in the remodeling project by reducing the depth of water.

It will also be necessary to secure the foundations of the Roorkee bridge and the curved retaining wall on the right bank, down-stream, against the effects of the erosion, which will certainly take place at and below the point where the section, and with it the velocity of current, changes.

8. From para. 111 of the Committee's report, I gather that they consider it necessary to lower the floorings of bridges between Roorkee and the Futtehgurh branch head to the same, or a somewhat similar, extent to that contemplated in the remodeling.

If the new declivity, or 1 in 13,500 be adopted, they can be adjusted to levels not differing much from those shown in the longitudinal section. The resulting state of things will be clearer by a perusal of the following table :—

Name of work.	Height from bed to		Depth of water.	Surface of water	
	Crown of arch.	Springings.		Below crown of arch.	Above springings.
Guneshpoor bridge, ...	25·68	13·68	14·5	11·18	0·82
Asuffnuggur falls, ...	13·35	..	14·5	..	..
Munglour bridge, ...	22·00	10·00	14·5	7·50	4·50
Liburheree bridge, ...	27·65	15·65	14·5	13·15	„
Nundowlee bridge, ...	23·86	11·86	14·5	9·36	2·64
Mahmoodpoor falls, ...	13·35	..	14·5	..	..
Dhimat bridge, ...	22·00	10·00	14·5	7·50	4·50
Toghulpoor bridge, ...	25·15	13·15	14·5	10·65	1·35
Nirgajnee falls, ...	12·35	..	14	..	..
Bailra bridge, ...	23·68	11·68	14	9·68	2·32
Bhopa bridge, ...	21·46	9·46	14	7·46	4·54
Jowlee falls, ...	11·35	..	14	..	..
Futtehgurh branch head, ...	16·00	..	14	2·00	..

From this it appears that the water will stand above the intrados of the existing arches at each fall. Raising those arches with the roadways will then, in my opinion, become a necessity, if the works are to be placed in a *permanently* safe condition.

The headway for navigation in five out of the eight bridges will be less than the standard (10 feet) assumed in the project, and approved by the Government of India; in three out of the five it will be only $7\frac{1}{2}$ feet.

The walls and arches of the locks it will be necessary to raise 3 feet higher than was estimated for in the remodeling project. In three of the bridges, the water will stand $4\frac{1}{2}$ feet above the springing lines of the arches, and thus the area of water-way will be still more contracted.

The mean width of section of the earthen channel, given in para. 7 of this paper, is 171 feet while the aggregate water-way through the present bridges is but 165 feet.

And, lastly, the surface of the stream at full supply, which in the remodeling scheme was projected just "within soil," will stand about 3 feet above the natural level of the ground. Whether this will necessitate raising the present embankments, I cannot say, not having the sections of the banks by me to refer to.

9. The superstructure generally of all the falls, old and new, must be raised to provide for the descent of a body of water $14\frac{1}{2}$ feet, instead of $11\frac{1}{2}$ feet deep.

At the Futtehgurh branch head, the side arches and roadway, must be raised 8 feet instead of 5 feet, to give the requisite headway for navigation.

10. As to the proposal in para. 112 of the Committee's report, to dispense with the cistern in the new falls, and thus lessen the time required for the execution of this work, I cannot think that the extra depth given to these cisterns could materially affect the question. Once the supply from the Ganges was cut off, the water from land springs could be kept under by ordinary lifting machinery, or if that proved insufficient, by steam pumps.

11. If the channel be enlarged, as projected in the remodeling scheme, and the bridges from Roorkee to the Futtehgurh branch head be left with their present water-ways, the current through the arches will be increased from 2·7 to 3·6 feet per second; and that erosive action will in consequence take place in the channel below, there cannot I think be a doubt; though it will probably be confined to a limited distance below the bridges, beyond which the reduced velocity will prevent channelling out, and the consequent depression of the water surface generally. It would be necessary however to strengthen the boulder talus below each bridge, and to protect the sides of the tow-path to the point where the increased action ceases; the acceleration of velocity through the bridges would of course be a hindrance to navigation to a certain extent.

Even taking the cost of the excavation into consideration, the balance of argument appears to me, as it has from the first, to be largely in favor of widening the channel, although the water-ways of the bridges may not be increased to a corresponding extent. With the lesser depth of water there is a surer prospect of permanence, the fluctuations in the surface of the stream will be less, and fewer repairs likely to be required hereafter.

The period of the special closure of the canal is in no way affected by the alter-

ations to the channel; all the work above the present water line can be done, while the canal is running; anything below that level could be completed within the limits of an ordinary closure.

It is also to be borne in mind that even if the widening be dispensed with, a considerable proportion of the estimated outlay will still be required for cutting down, re-forming, and repairing the tow-paths, on the existing channel, if navigation be considered a matter of importance.

12. If the present mean width of the channel be retained, the length of crest at the falls will of course be less than that provided for in the remodeling estimate; any savings, however, in this direction will probably be expended if they are not exceeded in the cost of additions to the height of the superstructure and to the lower flooring, no reduction of the aggregate outlay is therefore to be expected from this source.

13. The deductions from the estimates if the recommendations of the Committee be carried out, will be as follow:—

	Rupees.
Estimate No. 1. Excavation.	
From heads to the projected fall at Roorkee, ..	77,944·9
From Roorkee to Futtehgurh branch head, ..	3,36,949·9
Estimate No. 3. Khunkhul bridge, ...	34,703·17
Estimate No. 10. Rutmoo works (part, as per detailed statement), ...	5,619·12
Estimate No. 11. Peeran Kulliar bridge (part as do.),	1,296·75
Estimate No. 12. Muhewur bridge (part as do.), ..	1,275·72
Estimate No. 13. Solanee aqueduct (part as do.), ..	9,998·40
Estimate No. 14. Roorkee bridge, and curved retaining wall, ...	1,995·60
Estimate No. 15. Fall, 4·07, at Roorkee, ...	71,753·61
Estimate No. 16. Additions to Guneshpoor, Liburheree, and Dhimat bridges, ...	41,306·49
Estimate No. 20. Ditto to Mundowlee, Toghulpoor, Belra and Bhopa bridges, ...	49,182·32
Total Rupees, ..	6,32,025·98
5 per cent contingencies, ..	31,601·29
Rupees, ..	6,63,627·27
7 per cent. establishment, ..	46,453·91
Total deductions, ..	7,10,081·18

The aggregate estimate for the remodeling will not however be reduced by the whole of this amount.

It has been shown elsewhere that some expenditure will still be necessary on the present channel; the bridge floorings must be secured to an extent not contemplated in the remodeling estimates, the bed of the earthen embankment across

the Solanee valley must be pitched, and provision must be made below Roorkee for an increased depth of water. These additions may be roughly estimated as follow; details will be found in a statement appended to this paper:—

	Rs.
Excavation, ...	75,000·00
Securing floorings of Kunkhul, Peeran Kulliar, and Muhewur bridges, 3 × 2,423·6	7,270·80
Additional security to flooring of Rutmoo regulating bridge, ...	3,526·00
Pitching bed of Solanee embankment, ...	1,22,976·00
Securing floorings of eight bridges below Roorkee; erecting tow-paths under arches; and pitching slopes down-stream 8 × (3,196·4 + 420), ...	28,931·20
Securing floorings, &c., Roorkee bridge, ...	4,627·20
Raising water-wings and ghâts, Munglour bridge, ..	480·48
Raising at Bhopa and Dimat bridges, 195·36 × 2, ..	390·72
Raising arches and enlarging gratings at the four old falls below Roorkee, 4 × 9,027·44 = ...	36,109·76
Raising walls of lock chambers, and fitting new gates to four old locks, 4 × 5,552·58, ...	22,210·32
Additional raising in superstructure, &c., at Futtehgurh branch head, ...	7,519·89
Total Rupees, ..	3,09,042·37
Add 5 per cent. contingencies, ..	15,452·11
	3,24,494·48
Add 7 per cent. establishment, ..	22,714·61
Total additions, Rupees, ..	3,47,209·09
Total deductions from the estimates, as shown above,	7,10,081·18
Difference, Rupees, ..	3,62,872·09

that is, the saving on the aggregate estimate of Rs. 39,19,849, amounts approximately to Rs. 3,62,872, or about one-eleventh of the whole.

On the estimate for the remodeling from the heads to the Futtehgurh branch bifurcation, amounting to Rs. 13,60,702, the saving is something more than one-fourth.

The above is confessedly a rough calculation; some other items of expenditure due to the increased depth of water, may possibly have been omitted, above the falls at least some raising of the embankment *may* be found necessary.

14. From the Futtehgurh branch bifurcation to that of the Cawnpore and Etawah branches, at the termination of the main line below Allygurh, the estimate provided for cutting down and forming a tow-path 15 feet wide on the left bank, and a berm 5 feet wide on the other; as well as increasing the bottom and mean width of channel to the following extent:—

	Miles.		Feet.	Increase to Bottom Width.	Main Width.
From ..	50	..	2,530	28 ..	36·5
To ..	53	..	2,347		
From ..	53	..	2,347	13 ..	21·5
To ..	62	..	1,950		
From ..	62	..	1,950	23 ..	31·5
To ..	76	..	0		
From ..	76	..	0	8 ..	16·5
To ..	105	..	3,112		
From ..	105	..	3,112	1 ..	11·5
To ..	110	..	1,746		
From ..	110	..	1,746	4 ..	11·5
To ..	148	..	3,861		
From ..	148	..	3,861	7 ..	15
To ..	151	..	5,024		
From ..	151	..	5,024	5 ..	11
To ..	163	..	1,957		
From ..	163	..	1,957	9 ..	15
To ..	177	..	4,446		
From ..	177	..	4,446	16 ..	21·5
To ..	180	..	4,657		

The total estimated cost of the remodeling on this section amounted to Rupees 21,32,304, of which Rupees 5,13,063 is due to excavation only. I have not the actual sections of channel to calculate from; but I believe I shall not be far from the mark in stating that fully half, if not more, of the latter sum would still be required, even if the channel be not widened, in repairing the banks and forming the berms; while the masonry works would cost more from the depth of water being increased.

15. If the proposed alterations in the scheme for remodeling could affect the length of the closure of the canal required for the execution of the works in a material degree, they would no doubt be advisable on the score of economy; but inasmuch as all the projected new falls (except one) on the construction of which the length of the closure mainly depends are still considered to be indispensable; no saving in this respect can I think be looked for; while, as I have stated elsewhere, the arguments in favor of adhering to the original designs in all important points; if the rectification is to be a permanent one, appear to me, after a careful reconsideration of the whole question, to be quite conclusive.

(Signed) J. CROFTON, MAJOR, R.E.,

Chief Engineer, Irrigation Works,

Punjab.

18*th August*, 1866.

APPENDIX.

Detail of deductions from estimates, if the recommendations of the Committee be carried out.

Estimate No. 10. Rutmoo works:—	
Lifting old boulder talus, ...	165·20
New boulder talus, ...	4,273·92
Piling, ...	1,180·00
Total Rupees, ..	5,619·12
Estimate No. 13. Solani aqueduct:—	
Staking bed of earthen embankment, ...	9,450·00
Masonry in raising edge of roadways across aqueduct, ...	548·40
Total Rupees, ..	9,998·40
Estimate No. 11. Peeran Kulliar bridge:—	
Total estimate, ...	1,674·05
Deduct tow-path, ...	377·30
Saving, Rupees, ..	1,296·75
Estimate No. 12. Muhewur bridge,:—	
Total estimate, ...	1,871·32
Deduct tow-path, ...	595·60
Saving, Rupees, ..	1,275·72

Detail of additions to estimates if Committee's recommendations be carried out.

1. Excavation.—The total estimate for the excavation from the heads to Roorkee is Rs. 77,944·9; supposing that Rs. 30,000 of this are due to re-forming the tow-path, &c.; the distance being nearly 20 miles, the approximate rate per mile would be Rs. 1,500. The total distance from heads to the Futtehgurh branch bifurcation is 50½ miles. Expenditure on excavation

will then be $50 \times 1{,}500 =$ Rs. 75,000.

2. To secure the floorings of the Kunkhul, Peeran Kulliar and Muhewur bridges, an addition of at least 40 feet in length to the boulder talus, down-stream, will I think be necessary. This would give for each bridge

$119 \times 40 \times 3 = 21{,}480$ cubic feet boulder work,

Piles ($10' \times \frac{3}{4}' \times \frac{3}{4}'$ each) 230,

then

21,480 cubic feet boulder work, @ 7 Rs. per 100 cubic feet,	1,503·6
230 piles, @ 4 Rs. each, ...	920·0
Total Rupees, ..	2,423·6

3. At the Rutmoo, an additional length of talus will also be required, say 50 feet, then

$$236 \times 50 \times 3 = 35{,}400 \text{ cubic feet boulder work;}$$

and

35,400 cubic feet boulder work, @ Rs. 7 per 100 ..	2,478
262 piles, @ 4 Rs. each, ...	1,048
Total Rupees, ..	3,526

4. Pitching the bed of the Solanee embankment with boulders 1 foot deep.

Distance from Muhewur to Roorkee, ...	14,578 feet.
Deduct masonry aqueduct, ...	914 „
Length to be pitched, ..	13,664 „

Contents = 13,664 × 150 × 1 = 2,049,600 cubic feet.

Boulders, 2,049,600 cubic feet, @ 6 Rs. per 100, .. 1,22,976

5. Below Roorkee bridge an additional talus, not less than 80 feet in length, will be required, and the curved retaining wall will need protection for at least 200 feet below the bridge.

Contents	179 × 80 × 3 = 42,960	
	200 × 10 × 5 = 10,000	52,960

Boulder work, 52,960 cubic feet, @ 7 Rs. per 100 ..	3,707·20
Piles ditto, 230, @ 4 Rs. each, ...	920·00
Total Rupees, ..	4,627·20

6. An additional length of talus, as for the bridges above Roorkee, and tow-paths under the arches will be required for each of the eight bridges between Roorkee and the Futtehgurh branch head.

Talus, as above, ...	2,423·6
Tow-path, 12 feet wide, as estimate, ...	772·8
Total each bridge, ..	3,196·4

The waterwings and ghâts of three out of the eight bridges it will be necessary to raise about 3 feet in consequence of the increase to the depth of water from $11\frac{1}{2}$ to $14\frac{1}{2}$ feet.

Munglour bridge.

Ghats, up-stream, 2 × 41 × 8 × 3 ..	=	1,968 cubic feet.
Waterwings, down-stream, 2 × 18 × 2 × 3 ..	=	216 „
Total, ..		2,184 „
2,184 cubic feet brick work, @ 22 Rs. per 100, ..		.. 480·48

Bhopa and Dhimat bridges:—

For each,

Waterwings, 4 × 37 × 2 × 3 = 888 cubic feet.

888 cubic feet, @ 22 Rs. per 100, ... Rs. 195·36.

The sides of the channel for about 100 feet below each of the bridges will require pitching.

For each,

Contents 2 × 100 × 21 × 1 = 4,200 cubic feet.

4,200 cubic feet pitching, @ 10 Rs. per 100, ... 420.

7. It will be necessary to raise the arches and roadways of the four falls between Roorkee and the Futtehgurh branch head to about the same extent as those of the upper Bahadoorabad fall above Roorkee.

From Estimate No. 6, we obtain the detail as follows:—

Demolition of old work, 18,280, @ 1 Re. per 100, ..	182·80
Arching, 12,456, @ 28 Rs. per 100, ...	3,487·68
Masonry, 12,518, @ 22 Rs. per 100, ...	2,753·96
Earthwork, 96,000, @ 2 Rs. per 1,000, ...	192·00
Total for each, ..	6,616·44

The gratings at each of the four falls must be enlarged to provide for the passage of water, 14½, instead of 11½, feet deep; the additional cost will not be under one-third of the amount calculated in the "remodeling" estimate.

	Rs.
Total cost, as per Estimate 17, ...	7,232·80
Addition for each fall, ⅓ × 7,232·80 (gratings), ...	2,411·00
Raising arches, as above, ...	6,616·44
Total for each, ..	9,027·44

8. The walls of the locks in connection with the above it will be necessary to raise about 3 feet: new lock gates will also be required.

Raising Walls, c. ft.

Contents, 2 × 158 × 3 × 3 = 2,844

1 × 158 × 8 × 3 = 3,792 6,636

Lock gates, 2 × 9·54 × (12·5 × 20·5) = 629·64 superficial feet.

	Rs.
Brickwork, 6,636 cubic feet, @ 22 Rs. per 100, ..	1,459·92
Lock gates, 629·64, superficial feet, @ Rs. 6-5-0 per foot, ...	4,092·66
Total for each, ..	5,552·58

9. At the Futtehgurh branch head the superstructure must be raised 8 feet instead of 5 feet.

Lock walls, &c., also 3 feet higher.

Contents of masonry in raising Superstructure 5 feet, as per Estimate No. 25. 28,837·5 cubic feet.

$\frac{3}{5} \times 28{,}837{\cdot}5 = 17{,}302{\cdot}5$ cubic feet.

Lock walls and waterwings 3 feet higher than estimated.

Contents	$2 \times 127 \times 7 \times 21 =$	37,338	
	$27 \times 3 \times 15 =$	1,215	
	$30 \times 3 \times 11 =$	990	39,543
Deduct contents as per Estimate 25,			28,842
	Addition,		10,701 cubic feet.

Additions to gates:—

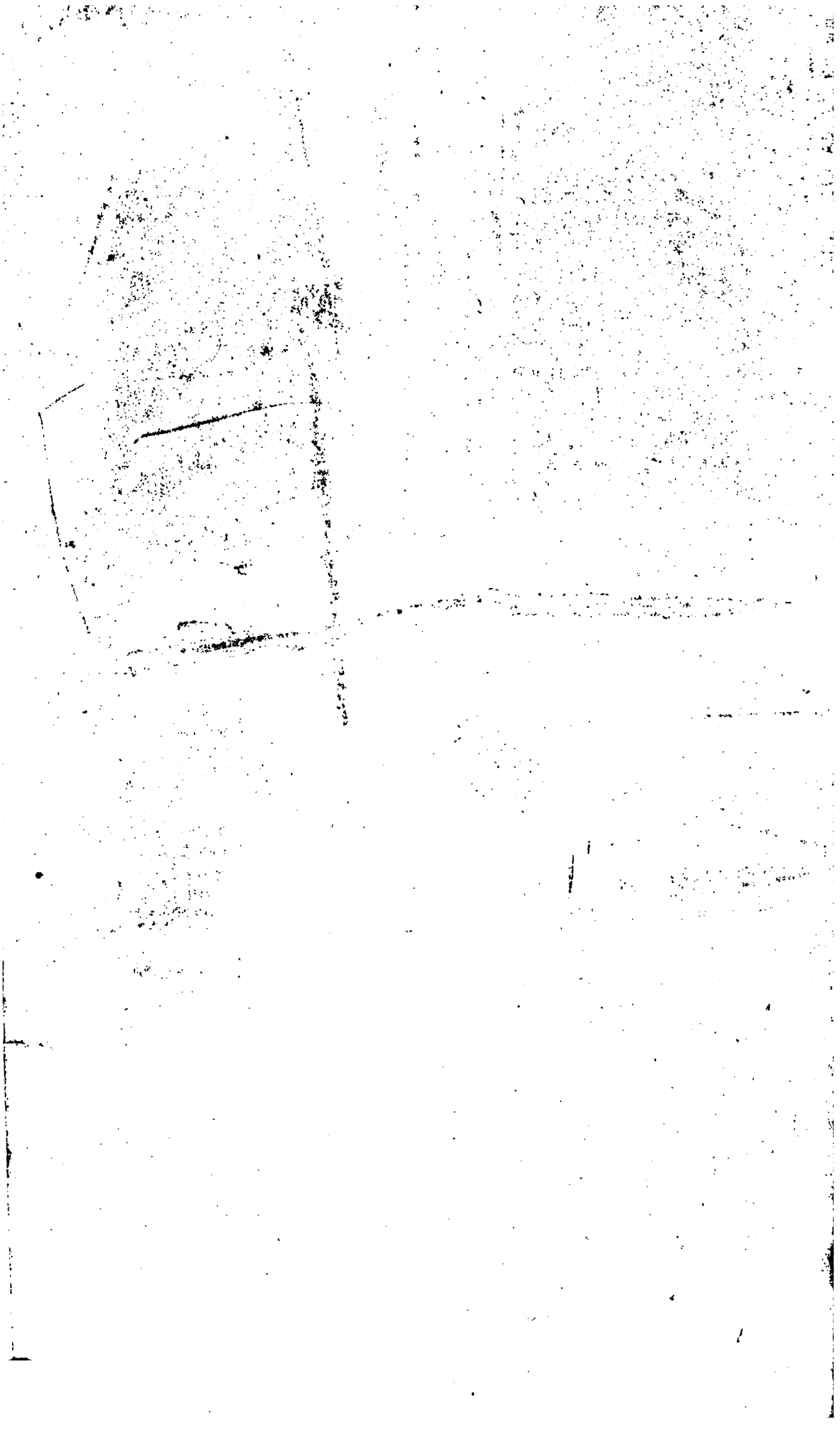
Lock gates, $2 \times 9{\cdot}54 \times \{\frac{3}{3}\}$ = 114·48 superficial feet.

Drop gates, Regulating bridge, } $2 \times 20{\cdot}5 \times 3 =$ 123 „

ESTIMATE.

c. ft.		Rs.
28,003·5	Brickwork, @ Rs. 22 per 100, ...	6,160·77
s. ft.		
114·48	Lock gates, @ Rs. 6-5-0 per foot, ...	744·12
123·0	Drop gates, @ Rs. 5 per foot, ...	615·00
	Total Rupees, ..	7,519·89

(Signed) J. CROFTON, MAJOR, R.E.,

Chief Engineer, Irrigation Works,

Punjab.